High-Resolution Atmospheric Modeling over the Philippine Archipelago

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LONG-TERM GOALS

The long-term goal of this project is to provide and evaluate high-resolution atmospheric forcing for the Philippines Experiment (PHILEX) and Assessing the Effectiveness of Submesoscale Ocean Parameterizations (AESOP) communities and explore the sensitivity of atmospheric and ocean model forecasts to horizontal resolution along the U.S. West Coast and in a complex archipelago. It is anticipated that in order to meet future Navy requirements, a better understanding of the numerical model requirements for horizontal resolution and atmospheric forcing are needed in coastal and complex archipelago regions.

OBJECTIVES

The objectives of this project are to (a) provide high-resolution atmospheric modeling support for ocean modeling over the Philippine archipelago and U.S. West Coast and (b) evaluate the sensitivity of atmospheric and ocean model forecasts to horizontal resolution in the Philippine Straits.

APPROACH

Accurate ocean prediction in coastal regions such as the U.S. West Coast and the Philippine archipelago will likely be dependent on obtaining atmospheric forcing fields with sufficient fidelity to represent the complex airflow through the various straits, around the numerous island chains, and in coastal regions. The approach used in this study is to apply the existing atmospheric and ocean data assimilation and modeling infrastructure within the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS[®][1]) to provide high-resolution atmospheric fields to support ocean modeling research over the Philippine archipelago and U.S. West Coast. COAMPS is comprised of four major components: the NRL Atmospheric Variational Data Assimilation System (NAVDAS) for the formulation of atmospheric analyses; the NRL Coupled Ocean Data Assimilation System (NCODA) system for constructing ocean analyses; a nested, nonhydrostatic atmospheric model; and the NRL Coastal Ocean Model (NCOM). Fully interactive two-way coupling is proposed within another project and is expected to be available for use in this project beginning in the latter part of FY07. A generalized flux coupler has been developed that allows one-way and two-way coupling of the COAMPS and NCOM models. COAMPS has been successfully applied to numerous atmospheric and ocean phenomena in many parts of the world.

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[1] COAMPS[®] is a registered trademark of the Naval Research Laboratory.

Report Documentation Page

1. REPORT DATE **30 SEP 2007**	2. REPORT TYPE **Annual**	3. DATES COVERED **00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE **High-Resolution Atmospheric Modeling Over The Philippine Archipelago**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

The Philippine archipelago is characterized by a spectrum of different straits ranging from relatively wide, ~100 km, to narrow, with widths less than 20 km. We anticipate that mesoscale atmospheric circulations, such as land-sea breezes, flow constrictions through straits, and deep convection, as well as large-scale circulations such as the Asian monsoon will be important factors in determining the atmospheric conditions over the Philippine archipelago. We propose to evaluate COAMPS atmospheric and ocean model forecasts at various horizontal resolutions to gain a better understanding of the resolution required for accurate depiction of the oceanic conditions through the various straits that comprise the Philippine archipelago. We will apply statistical methods to ocean forecasts from the one-way and two-way coupled simulations using both ocean observations and verifying ocean analyses. Data available from the Fleet Numerical Meteorology and Oceanography Center (FNMOC) and the Global Ocean Data Assimilation Experiment (GODAE) will be supplemented with that from field programs and used to produce regional analyses. The statistics for model forecast error will be compared to those of other models and the errors of persistence and climate as well.

WORK COMPLETED

1. High-Resolution Atmospheric Forecasts in Support of the AESOP Community.

In FY07, we continued running a COAMPS area using 4 nests (81, 27, 9, and 3 km) for the eastern Pacific for support of atmosphere/ocean modeling on the west coast of the U.S. Forecasts of 48-h duration are being generated twice-daily in real-time (0000 and 1200 UTC), with the fields necessary for ocean model forcing transferred in real-time to a ftp server. Completion of this historical dataset dating back to 2002 will allow ocean researchers to use high-resolution COAMPS fields for forcing ocean models for historical cases and/or long-term spin-up runs.

2. High-Resolution Atmosphere and Ocean Simulations in Support of the PHILEX Community.

Prior to the PHILEX exploratory cruise, we have performed reanalyses for two time periods (summer and winter 2005) over the Philippine archipelago using COAMPS with three nested grids with horizontal resolutions of 72, 24, and 8 km on the finest grid mesh. The purpose of the reanalyses is to create atmospheric datasets that contain sufficient fidelity to force ocean models, thus making it possible for PHILEX scientists to gain a better understanding of the atmospheric and oceanic conditions in the Philippine region. These simulations and reanalyses are being used to shape the observational program in FY08.

Fields from the COAMPS 8 km nest were used to force regional NCOM (3-km resolution) configured for the entire Philippines area. The ocean model was driven by hourly momentum and heat fluxes from COAMPS and received initial and lateral boundary conditions from the data-assimilating global HYbrid Co-ordinate Ocean Model (HYCOM). A goal of this work is to investigate the impact of high-resolution atmospheric forcing on the ocean circulation in the vicinity of straits and complex bathymetry.

RESULTS

1. High-Resolution Atmospheric Forecasts in Support of the AESOP Community.

Figure 1 is an example of a 3-km resolution COAMPS forecast during AESOP that was made available to the community. The forecast was initialized at 00UTC 15 August 2006. The 10-m wind speed and direction, shown in Fig. 1, illustrates a flow transition that takes place during a relaxation condition period (Fig. 1a) that changes rapidly to a strong northwesterly flow (Fig. 1b). The northwesterly flow direction within the marine boundary layer is the norm from a climatological perspective during the summertime months along the U.S. West Coast. The strong northwesterly flow interacts with numerous capes and bays and results in localized regions favorable for enhanced upwelling.

During AESOP in 2006, COAMPS was executed in real-time and the fields necessary to force ocean circulation models were made available to the AESOP community on an anonymous server and archived on a large server at NAVO. A continuous archive exists for the 81, 27, 9, and 3-km domain configuration from 1 January 2002 through current date in 2007. These fields can be used to force ocean models for historical cases and/or long-term spin-up simulations.

2. High-Resolution Atmosphere and Ocean Simulations in Support of the PHILEX Community.

Triply nested high resolution COAMPS Philippines simulations were compared with QuikScat satellite measurements of wind stress during February 2005 (Figure 2). The intense wind jets are a persistent feature during winter monsoon conditions. The correspondence with remotely-sensed wind stress is high while also demonstrating features, such as the individual island tip jets that merge offshore to form a larger wind jet, that appear to be below the resolution of the satellite sensor. Atmospheric wind jets are absent during the simulations of the summer monsoon. It is hypothesized that the relatively shallow boundary layer capped by a subsidence inversion during the winter monsoon causes the flow to be more sensitive to terrain. In contrast, the deeper boundary layer during the summer monsoon likely enables the low-level flow to easily ascend the terrain and cause diurnal heating effects to dominate then.

The bands of alternating positive/negative wind stress curl caused by the wind jets force a characteristic eddy field in the coastal waters off the island of Mindoro. This dynamic eddy field usually contains a cyclonic (cold core) cell off the northwest tip of Mindoro and a counter-rotating anticyclonic (warm core) gyre west of Mindoro. This cold/warm region of surface waters is evident in satellite SST (Figure 3), and is the subject of our ongoing investigations into coupled air-sea interactions.
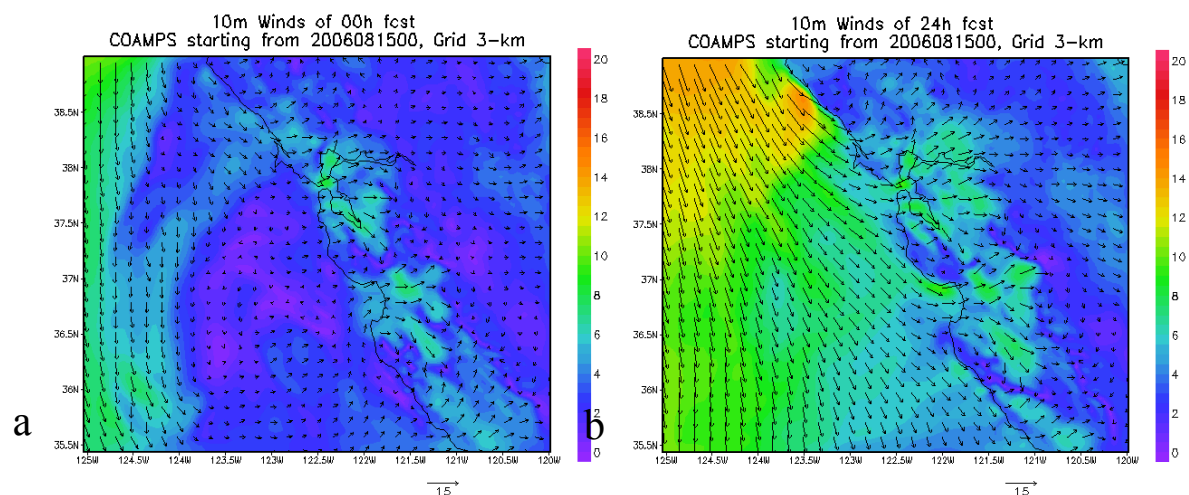
***Figure 1. Forecast wind speed at the 10-m level for the a) analysis time and b) 24-h
forecast time for a forecast initiated at 00UTC 15 August 2006 during AESOP program.***
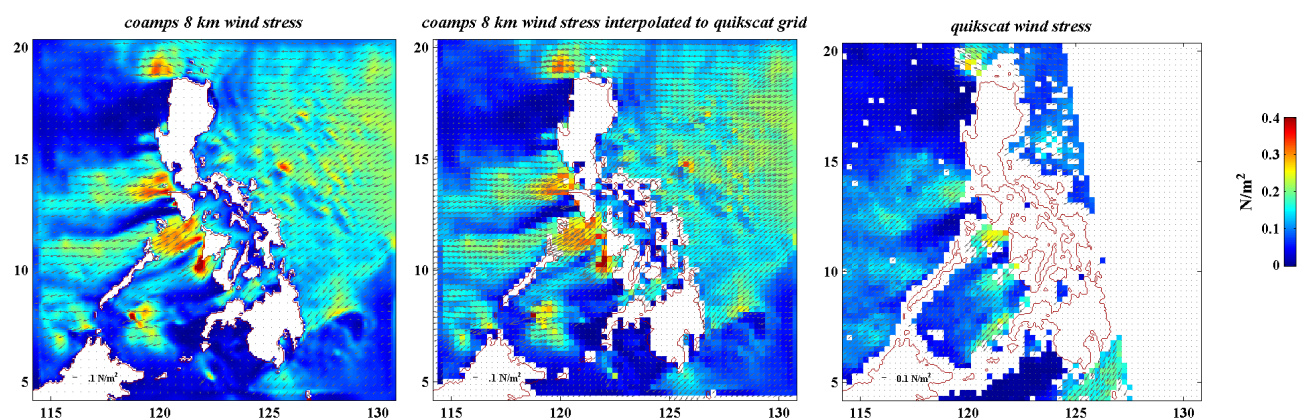

***Figure 2. COAMPS and QuikScat wind stress for 21 UTC 7 February 2005.
Left panel: 8 km native model grid field; center panel: model field interpolated to
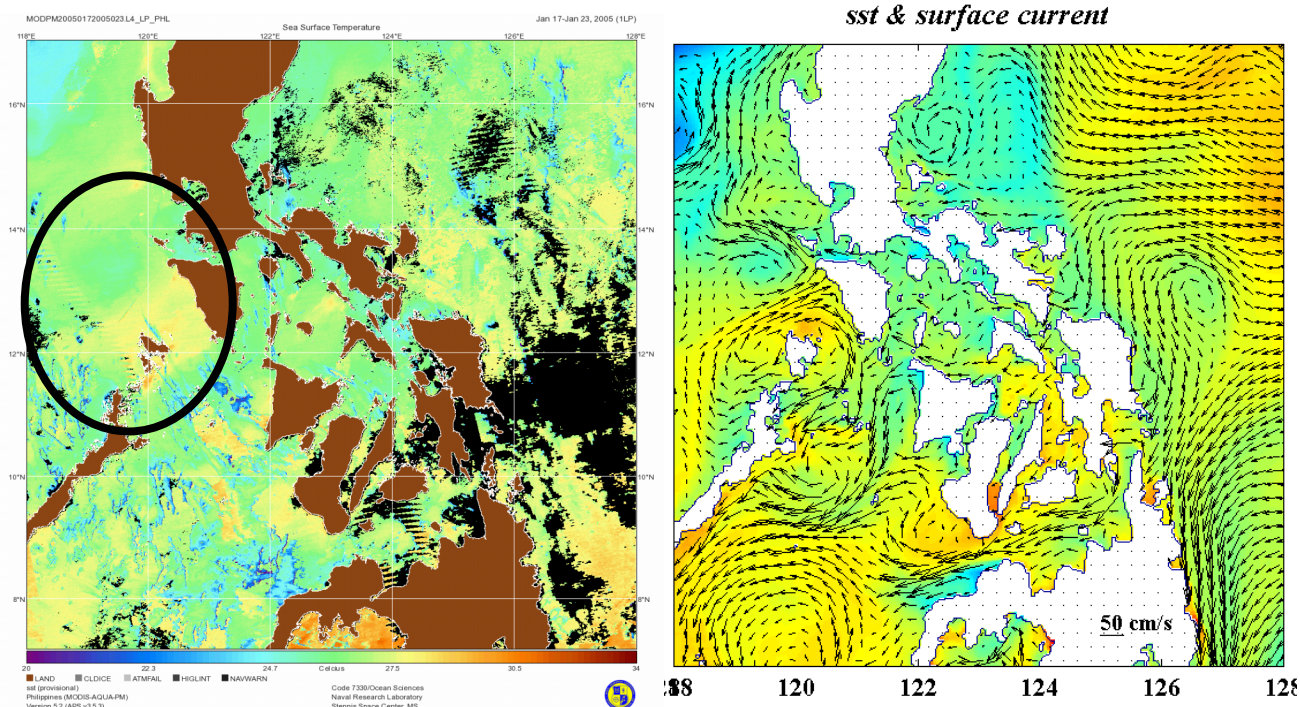QuikScat processing grid; right panel: QuikScat wind stress.***

***Figure 3. Left panel: MODIS satellite SST composite for 17-23 January 2005
(courtesy of Bob Arnone, NRL_SSC). Right panel: NCOM 3 km resolution
surface temperature and ocean current mean field for the same time period.***

IMPACT/APPLICATIONS

An accurate environmental representation of the atmosphere and ocean is critical for littoral sea control, theatre air and missile defense, homeland defense, undersea warfare, and special operations. With the ability to simultaneously predict the state of the seas and weather at very high resolution over the battlespace, defense planning would achieve an unprecedented breadth in characterizing the operational environment. This new capability, which has been requested by users in order to depict the battlespace environment, has direct implications for planning and executing special operations. Information from the ocean boundary layer, such as currents, temperature, and salinity, are necessary for applications to Navy Special Warfare (NSW), search and rescue operations, mine countermeasures (MCM), and anti-submarine warfare (ASW). Accurate predictions of the atmosphere and ocean boundary layers require very high-resolution models that include the necessary complex physics, to describe how the coupled atmosphere-ocean boundary layer structures evolve in time. This capability requires the mesoscale meteorological model be coupled to an ocean model to properly resolve the complicated fluctuating conditions in coastal regions. The characterization of the coupled atmosphere-ocean environment must be done through an integrated system that relies on observations, data assimilation methodology, and numerical modeling for both the atmosphere and the ocean. Our research will include identifying the advantages of high-resolution in regions of complex island geometry and gaining insight into coupled modeling issues using one-way and two-way interactive approaches in these challenging regions. Knowledge of shifting environmental conditions will confer more power in crafting strategy, and will allow the Navy to operate with more flexibility.

TRANSITIONS

The next generation COAMPS system will transition to 6.4 projects within PE 0603207N (SPAWAR, PMW-180) that focus on the transition COAMPS to FNMOC.

RELATED PROJECTS

COAMPS will be used in related 6.1 projects within PE 0601153N that include studies of air-ocean coupling, boundary layer studies, and topographic flows and in related 6.2 projects within PE 0602435N that focus on the development of the atmospheric components (QC, analysis, initialization, and forecast model) of COAMPS.

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None.

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